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23.2: Current Capabilities of the Finite-Element MICHELLE Gun & Collector Simulation Code*

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Abstract: *The MICHELLE code is a Finite-Element Electrostatic Particle in Cell code for application to 2D and 3D particle beam formation, transport, and collection. Its primary development focus has been for DC electron guns and depressed collectors; however, it has other applications such as RF electron guns, ion thrusters, photocathodes, etc. Its ability to manage large mesh sizes and large particle counts in complex geometries requiring the resolution of disparate spatial scales in 2D and 3D on desktop computers has allowed it to be applied to devices that could not have been readily modeled in recent years. This presentation gives an overview of the current status of MICHELLE. In particular, application to time-dependent problems will be illustrated.*

Keywords: MICHELLE; electron gun; depressed collector; electrostatic simulation.

Introduction

The MICHELLE [1], [2] two-dimensional (2D) and three-dimensional (3D) steady-state and time-domain particle-in-cell (PIC) code has been employed successfully by industry, national laboratories, and academia and has been used to design and analyze a wide variety of devices, including multistage depressed collectors, gridded guns, multibeam guns, annular-beam guns, sheet-beam guns, beam-transport sections, and ion thrusters.

Recent work has included time dependent application for photoemission gun applications. Time domain effects in collector modeling has shown to be an important effect to capture. Also, including dielectrics in simulations of some variety of gun designs has shown significant effects on beam size, and guns operating in the transition from space charge limited to temperature limited require special attention to accurately predict the gun performance. Modeling thermal beams through guns and into transport regions multiplies the run time by a factor of about the increase in the number of particles to support a thermal beam distribution. Because of such cases, work has been proceeding on parallelization to hold run times down.

Applications

The photoemission modeling often includes the need to support RF cavity mode time-dependency in the MICHELLE run as well as the need for more sophisticated emission models. For the RF cavity modes, we have previously reported using MICHELLE under the STAAR ANALYST design environment [3] where RF cavity modes are calculated using ANALYST's 3D finite-element driven-frequency or eigenmode solvers and importing those fields into MICHELLE. In this case MICHELLE clocks those cavity modes, and emits particles using either a photoemission model or a thermionic emission model. In the case of photoemission, the NRL photoemission model [4] has been implemented into MICHELLE and supports time-dependent emission based on a time and spatially dependent laser profile on the emitter. For gridded guns, work proceeds on improving the effects on the emission due to the low voltage that occurs in the vicinity of the emitter and shadow grid. This low field emission situation in combination with complex field patterns in the vicinity of the emitter-grid region challenge emission models. See Fig. 1.

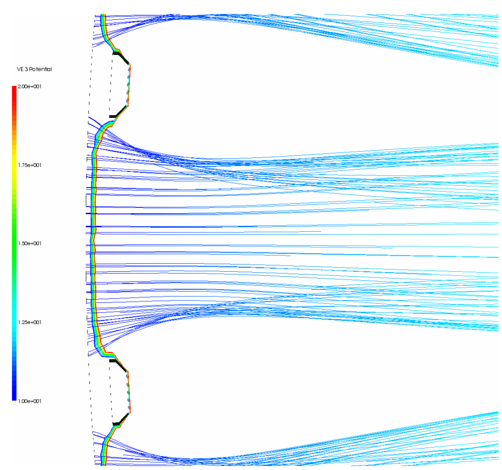

Figure 1. A detailed view of particle trajectories in a typical emitter-grid region.

It has often been the case that time-dependent effects are ignored in the modeling of spent beam collectors. In the

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typical vacuum tube, the beam entering a collector is often in one of two states; as a DC beam or as a spent beam resulting from an RF interaction. The DC beam entering the collector is easily treated by the steady-state algorithm. This regime of operation often gives the highest peak power loads, which is an important design constraint to manage in the development process. See Fig. 2.

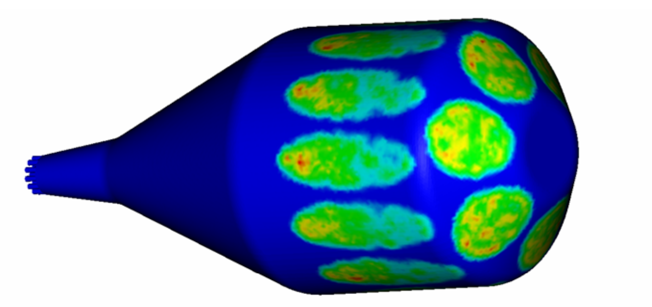

Figure 2. Power loading on 18-beam collector surface at full beam energy of 42 KeV.

However, the spent beam, which often can have a significant variation of current vs. time (see Fig. 3), is often modeled as a uniform steady-state beam with constant current vs. time. These particles are in danger of re-entering the interaction space, causing a loss of device performance and efficiency. Simulation of the beam entering a collector in this case is often flattened over an RF period, and injected with a time-averaged current so that the steady-state algorithm can be applied. This has been due to the widespread application of the steady-state algorithm due to its performance advantage over available time-domain codes. The use of time domain PIC codes have been less accepted due to time of computation and difficulty of use. For collectors, the problem is exacerbated because such EM PIC models have difficulty representing the small beams entering a large cavity. MICHELLE can apply its time-domain ES PIC model to this application. In this case, the spent beam from an interaction region (from an interaction code or a PIC code) is brought into the collector as a function of time. One RF period of the beam is required and it is repeated and injected into the collector domain until a time-dependent steady-state has been achieved. This gives a better representation of the actual collector function during RF operation, but more importantly highlights effects that may not be captured when the beam is treated as a uniform injection of current over time. An example is the NRL 18 beam MBK collector design where electrons from inner beams would reverse when they enter the collector cavity.

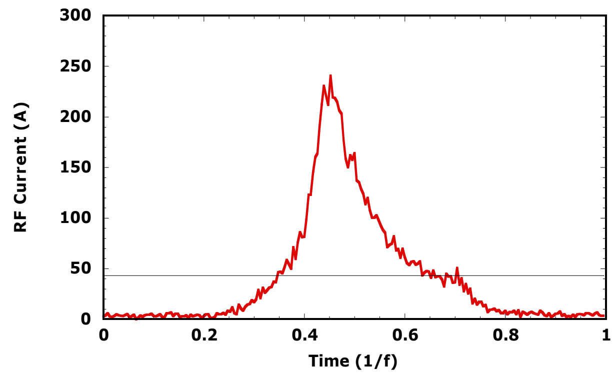

Figure 3. Beam RF current profile in a single period of the spent beam near saturation (average beam current of 41.6 A is also shown).

We will report on our progress in these areas as well as algorithms for modeling emission in the transition from space charge limited to temperature limited and our progress in parallelization.

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3. Analyst is a commercial finite-element package for electromagnetic design. www.staarinc.com.
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